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ART. V.—*Hayward's Physiology of Man.*

*Outlines of Human Physiology; designed for the Use of  
the higher Classes in Common Schools.* By GEORGE  
HAYWARD, M. D. Boston, 1834.

IT is a subject of no small degree of surprise that the science of Physiology has received so little attention, except from those to whom it is a necessary part of professional education. It might have been thought, that the structure and functions of the human body furnish sufficient matter for the curiosity and investigation of the general inquirer after knowledge, no less than for him to whom the study is of immediate practical necessity. Surely we are ‘fearfully and wonderfully made.’ Where else shall we look for such a specimen of mechanism, fitted with such matchless skill, for the accomplishment of an endless variety of purposes? To say nothing of the inscrutable apparatus, designed both as the residence and the instrument of the immortal mind.

And yet, curious and interesting as are these subjects, and fruitful as they are of most useful results, there are few persons among us, with the exception of medical men, whose curiosity is excited to study them. Of the wonders of the human body, the learned, in regard to general subjects, and the unlearned, are alike, or nearly alike, ignorant. If we sometimes, and it is rarely that we do, hear the preacher or the orator refer to a physiological phenomenon by way of ornament or illustration, the *antiquity* of the allusion is often betrayed by the reference to an old and discarded theory; the classic origin of the figure shows the sources of the author’s information. There is perhaps no branch of science, in regard to which such crude and incorrect notions so generally prevail. Aside from the medical profession, all are in the dark in respect to many wonderful phenomena, exhibited in the commonest functions of every-day life.

The common explanation, or rather apology for this state of general ignorance is, that the subject is involved in phraseology so technical, as to forbid the researches of those who do not make it the business of their lives to pursue it. It is true, that when followed out in all its details, medical science

includes the knowledge of many things, not known to ordinary men, to which names must be given ; and thus a language is created, as peculiar as the knowledge of which it is the instrument. But the general knowledge of physiology, of which we are speaking, demands no such intimate acquaintance with details. In point of fact, most of the physiological works published in modern times, although written for the profession without any especial care to avoid technical phraseology, may be read with facility by any man of ordinary intelligence ; and require less use of a glossary than the speculations of phrenology, which have at times excited so much popular curiosity.

A better reason for the inattention to physiology is, in our view, the want of a work on the subject, well suited to the habits and tastes of general readers. Those works designed for the medical profession, treating of the whole subject of human and comparative physiology, contain discussions not adapted to parlor reading ; and therefore the more suitable topics are disregarded or thrown out of favor, by the company in which they are found. There was a want of a treatise, which should present a comprehensive description of the general functions of the human body, while it should leave out of view such topics, as are necessary only to the physician. Such precisely is the work before us. Its purpose is well stated by the author.

'This work is intended for those who are unacquainted with the structure of the human body. It is an attempt to explain to them the uses of its most important parts, in familiar and popular language. It differs, therefore, in this respect, from most works on physiology, which suppose some knowledge of anatomy in those who read them ; and it does not treat of those topics, which, though highly important to professional students, could not with propriety be introduced into the studies of the young.'

'The author was induced to undertake it, in the hope that it might be useful to the young ; and his object will be effected, if it should open to them a new and interesting branch of knowledge. He was desirous that they should become acquainted with human physiology, as he felt confident, that they could not fail to see, in the structure and functions of their own bodies, the clearest evidence of wonderful contrivance and beneficent wisdom.'—*Preface.*

The work is intended primarily for the instruction of the young; we believe there are few, of any age, however, who have not made physiology a study, but will find in it a large amount of interesting and useful information; and to the physician, who has not recently renewed his application to this branch of knowledge, it furnishes a valuable condensed view of the different explanations and theories, as they are modified or illustrated by the more recent improvements in general science. It is 'designed for the use of the higher classes in common schools.' Yet we are not to infer that our author had any expectation or wish of making it a common school-book for little boys and girls, who should be studying their accidence and their grammars, instead of prying into the wonders of their own bodies. It is an older and more advanced class of learners that is included in this designation, who, having already acquired the more elementary branches of knowledge, may be allowed and encouraged, before they leave school, to lay in some stores of information in the more particular departments of learning. We fear that in our *common* schools, speaking literally, few classes will be found of scholars, who are properly qualified for thus entering advantageously upon studies of this sort. Some such there are, however, and for them this book is well adapted to be useful.

It might be hoped that a work like this, teaching the true principles of sound physiology, explaining the manner in which the great functions of human life are carried on, would be the means of correcting some of the errors of the prevailing systems of education. A little knowledge of the delicate structure of some of the organs most essential to life, and of their easy susceptibility, especially in childhood, to impressions unfavorable to health, should seem to be enough to show the danger of confining children to the school-room five or six hours at a session, daily, for years, on an uneasy bench, in a constrained posture, and often with such rigor, that to stoop and pick up a pin is marked as a misdemeanor, which counts, at the end of the year, in the estimate of character, and exerts an influence in the annual distribution of prizes. A mere glance at that wonderful organ, the brain,—that mysterious medium of communication between the immaterial mind and the material body, so curiously wrought, so delicate as scarcely to admit of examination, furnished with an immense supply of blood-vessels, which are excited to in-

creased action by every emotion,—the slightest hint of all this were enough, one would think, to give warning of the imminent risk with which children, at an age when bodily constitution and mental character both peculiarly expose them to injury, are forced, by hot-bed excitements, into studies, proper only to maturer years. The successive developments of the different powers of the mind are disregarded ; and at an age when little more than perception and memory are fully developed in the young mind, exercises are required, which can be properly performed only by calling into action the riper faculties of a much later period of life. Infants almost, and sometimes even in Sunday schools, are taught to reason, and to write their reasonings, when they should be storing up facts for future use ; and the sciences are taught to babes, who scarcely know their alphabet.

It is true, that most of these only learn to borrow the reasonings of others, while they are supposed to learn thus prematurely to think, and to substitute high-sounding names of technical science for the unpretending words of every-day life.\* Still the evil is the same. To the many, indeed, only self-conceit is taught instead of real knowledge ; and this is comparatively a small matter. A few years more of life may correct it, and give them a juster view of the extent and value of their acquirements. But the few,—had they been spared, they would have formed the very *élite* of society, they would in the coming generation have taken the lead in whatever is excellent in our institutions, and have raised the standard of meritorious attainment in them : the few, who really enter into the spirit of these precocious exercises, are often stimulated into disease and death. The premature exercise and excitement of faculties, which are yet in their infancy, either exhaust the powers of the mind, and leave the child in subsequent mediocrity or inferiority, or else they become the cause of inflammation or dropsy in the brain. That delicate organ cannot bear a long-continued and over-strained excitement, without great danger of permanent injury : and this injury may be exhibited either in impaired faculties of mind, or in the early death of its victim.

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\* ‘Grandpapa,’ said a bright little fellow, of three years old, who had studied his alphabet and geometry a few weeks at an infant school of science, and had learned the scientific name for a *post*, ‘Grandpapa, what do you have that *perpendicular* in your yard for?’

This is a subject of great importance, but we cannot farther pursue it here. We shall greatly rejoice, if the slight notice we have taken of it shall excite the attention of some, whose office it is to influence the public mind on matters of this sort.

We have said, that even a slight knowledge of physiology might correct these evils, and teach a better mode of education ; yet we have little hope that it will do so. And it is not altogether the fault of teachers that it will not. If parents are more solicitous of seeing their children prodigies, than reasonable beings, well endowed with sound learning, there is no alternative left to the teacher but to yield to the craving. He must select the most active and aspiring pupils, and press them forward into studies beyond their age, while the mass follow on in a round of lessons beyond their competency ;— or he will fail of the degree of *éclat*, that is necessary to secure him the possession of his station as an instructor of youth. How many mothers have mourned over the loveliest of their daughters, whose ingenuous spirits were thus stimulated into excessive and fatal action, cut off in their first opening into mature life ! The remembrance of an unwonted proficiency is now the balm for the wounds of affliction : the glory of unnatural attainments becomes the victim's wreath, and reconciles her weeping friends to the sacrifice.

We have already said, that the work before us is not designed to foster this destructive passion for precocious learning. We would fain hope it may do something to counteract it. Although we have spoken so discouragingly of the prospect of a speedy correction of an evil, which we certainly regard as a most serious one, we are not wholly without the hope, that a juster state of feeling may gradually be introduced into our community by the diffusion of information : and we know not where that information may better begin, than with some knowledge of the healthy functions of those bodies, which are so constantly exposed to injury.

There are some other of the customs of society, upon which a general dissemination of physiological information might be supposed to exert a favorable influence. The mother, who understands the essential importance of a free action of the chest, to a proper performance of the functions both of the heart and the lungs, might perhaps be less disposed to bind down the ribs of her daughters, in immovable casements of whalebone.

But we are not so sanguine as to expect, that the *dicta* of fashion can ever be reversed by science. And happily there is less in the habits of dress of the present day, than in some of the days gone by, to call forth either the admonition, or the unavailing lamentations of the severe guardians of the public health.

A still more direct influence might be anticipated, in the discouragement and diminution of quackery. The man, who knows something of the wonderful powers of steam, would feel more of apprehension in following a locomotive engine, conducted by an ignorant engineer, than he who had seen nothing but the outward form of the curious apparatus. In like manner, it is the almost universal ignorance of the complicated structure and curious performances of the several parts of the human body, that prompts so many to trust the management of its disorders to the hands of those whose knowledge, both of its healthy and its diseased functions, is as limited as their own.

After all, however, the chief ground of confidence of the usefulness of this little book is the great principle, that all knowledge is useful. It is essential only that the knowledge disseminated be accurate, and it must, sooner or later, do good. In this respect we have great pleasure in speaking of the work before us. Although wholly unpretending in its character and claims to notice, it has obviously been prepared with great care, and a scrupulous attention to accuracy in all its parts. We could wish that scientific works, designed for general readers, were always prepared with equal ability and care.

There is much, indeed, in the science of physiology, in which our knowledge is still imperfect. After all that the improvements of modern science have done to explain them, there are many parts of the human body, whose modes of action are still but very imperfectly understood. It becomes peculiarly important, therefore, in a work of this sort, that a careful discrimination be made between what is known, and that which rests upon theoretical speculation merely. This we are happy to say is faithfully done in the work before us. The reader is no where misled by opinions advanced as facts. The results of accurate observation are stated ; and the theories in explanation of the several phenomena are given as deductions from these observations. Wherever, as is often the case, the results of careful observation are inconclusive, the

reader is not palmed off with a theory confidently proposed, by way of substitute ; but is honestly informed of the deficiency of our knowledge in regard to the particular point. Some of the best explanations which have been attempted by different physiologists are then given, with the reasons in favor of them, and the reader is left to draw his own conclusions. The consequence will probably be, in most cases of this kind, that he will come to no conclusion at all. And this is just what it ought to be : since, if the evidence is such as to leave the best physiologists in doubt, it is not to be expected that those who are less instructed in the matter will understand it more clearly. All that they can here require is, that they shall be taught the full extent of the solid grounds which the several opinions have to rest upon, and a full demarcation of the line at which hypothesis begins.

To the casual reader, it may seem that so much is left unsettled, that little can be truly known ; and there have not been wanting those who have reproached medical science generally, as made up more of conjectures than of accurate knowledge. Nay, some have gone so far as to prefer the medical skill of those who discard all pretensions to knowledge, as if those, who are the boldest in their conjectures, are the most to be trusted.

There are two answers to this view of the matter. In the first place, most of the questions, in regard to which the greatest uncertainty prevails, relate to the manner in which a particular function is performed, the *modus operandi*, rather than to the character of the function itself. The action itself has been carefully observed and is well understood, but the means by which that action is carried on and directed, are involved in mystery. For example, it is perfectly well known that some impression must be communicated by a nerve to a muscle, to enable it to contract ; for if the nerves of any part are destroyed or divided, the muscles of that part wholly cease to act. But of the nature of the influence thus communicated, we are entirely ignorant. In a practical point of view, however, the *facts* which we know, are of incomparably more importance, than the explanation of those facts, which still remains hidden. Throughout the whole circle of human physiology, the functions of the several parts, with the phenomena which attend the performance of those functions in a state of health, and also the changes of structure and of action which the same

parts undergo in disease, have been and still are the subjects of careful observation and study. The attention of medical men, especially at the present time, is directed to the observation of facts, rather than to framing theories. Doubtless much remains to be learned. But we may well ask, in the second place,—supposing that there still is much of ignorance in the profession,—which is the safest guide through this ignorance, he who has learned something of its extent, and has done something to surmount it, and who has at least learned some caution in regard to what is unknown, by the difficulties by which he has acquired what is known ; or he who has learned nothing, and who leaps confidently in the dark, because he sees none of the pitfalls in the darkness by which he is surrounded ?

The arrangement of this work is simple and natural. After a short introduction, giving a concise account of the textures, or *systems*, which make up the composition of the human body, the author treats of the various functions ; and those are first examined, which are connected with the growth and nourishment of the individual being, and afterwards those which connect him with external objects.

'The animal body is composed of fluids and solids. The former constitute a much greater part of the whole than the latter ; being in the proportion of six to one, according to Richerand, and of nine to one, according to Chaussier, in an adult subject.' These fluids are divided into four classes ; 1st, those which form the blood ; 2d, the blood itself ; 3d, those that are formed from the blood ; and 4th, those that are returned to the blood from the various parts of the body.

'The solids are formed from the fluids by a process called secretion, which will be treated of in a subsequent part of this work. Much labor and research have been bestowed on attempts to ascertain how many elementary solids exist in the various organs of the body. Some have supposed that all the solids are formed from three elementary ones, viz. : the cellular, the nervous, and the muscular : and to these, others have added the osseous and membranous. It is believed that all the organs, however various they may appear, in their structure and composition, can be ultimately reduced to these five.'

'These simple textures or tissues, as they are called, being united in various proportions, form the compound tissues or systems. There are eleven of these systems, according to the arrangement of Dupuytren and Richerand ; these are

1. The Cellular.
2. The Mucous.
3. The Serous.
4. The Muscular.
5. The Osseous.
6. The Vascular.
7. The Nervous.
8. The Fibrous.
9. The Erectile.
10. The Horny, as the Nails and Hair.
11. The Parenchymatous, as the Glands.

The function first to be described, under this arrangement, is, of course, that of *digestion*. The apparatus for the performance of this function, the teeth and tongue, the parotid gland, and the stomach, are succinctly described. Then, after a short notice of the more important of the exploded theories of digestion, we have an explanation of the process, as follows.

'The opinion that is now most generally received respecting the mode in which the stomach acts on the food that is taken into it; is, that a peculiar liquor secreted by the stomach, and called gastric juice, has a solvent power, which enables it to reduce the food to an uniform mass.

'The introduction of food into the stomach, produces an increased secretion of the gastric liquor, which is poured out in such abundance in health, as to surround every particle of it. When this is accomplished, an alternate contraction and expansion of the stomach take place, and continue till the whole alimentary mass is converted into chyme. This motion is produced by the muscular coat of the stomach, which is formed, as has been before stated, by muscular fibres running in a longitudinal and transverse direction.

'It has been ascertained, that in a healthy stomach, the food, if easy of digestion, is converted into chyme, in four or five hours, and that before this change has taken place, it is prevented from passing into the intestine, by a sort of valve situated at the pyloric orifice of the stomach, called pylorus, or door-keeper. It has been supposed by some, that this valve has the property of determining when the aliment was sufficiently changed to allow it to pass, that it gives free exit to chyme, and contracts when undigested substances attempt to enter the duodenum.

'The food is not all converted into chyme at the same time; but as fast as it is changed, it passes into the intestine, only two or three ounces collecting in the pyloric extremity at once.

'The change which the alimentary mass undergoes in the first intestine or duodenum, as it is called, is as great and important as the one which is effected in it in the stomach. In that organ, it is converted into chyme, and the process is called chymification: in the intestine, it undergoes what is called chylification; in which it is brought into such a state, that a peculiar fluid, called chyle, can be extracted from it by the absorbent vessels, whose mouths open in great abundance into this intestine. This

chyle is a thin milky fluid, and these absorbents are thence called lacteals.

'The chyme passes slowly through the duodenum, and in its passage it becomes intimately mixed with the liquor secreted by the pancreas or sweetbread, and the bile which is formed by the liver. These fluids sometimes pass through separate tubes, and at others enter by a common canal. The inner coat of the first intestine is covered with folds of its lining membrane, which answer the purpose in some measure of valves, retarding to some extent the passage of the chyme, and preventing, under ordinary circumstances, its regurgitation. In this way, the absorbents have an opportunity of separating from it the chyle, the fluid which is afterwards to be converted into blood, for the nourishment of the body.'

'The chyle has frequently been examined, with a view of ascertaining its nature and properties. It has no inconsiderable resemblance to cream in appearance, and when removed from the body and suffered to stand, it undergoes a species of spontaneous coagulation. It separates into three parts, a transparent and colorless fluid, a firm and white coagulum, and a thin pellicle of fatty matter, which floats on the surface; a process not unlike that, which will be hereafter spoken of, as taking place in the blood when removed from the body.'

Another extract will show the purposes which the chyle, thus formed, accomplishes in the animal system.

'The process by which the body increases in size, and the waste of its organs is repaired, is called nutrition. Its agents are supposed to be those minute vessels, that are situated between the termination of the arteries, and the commencement of the veins, and which are known by the name of capillaries. These vessels are distributed largely to all parts of the body, and have the power of separating from the blood particles identical in character with those of which the various organs of the system are composed.'

'It has been before remarked, that a species of composition and decomposition is constantly going on in the body during life. The first of these is effected by the blood-vessels, and the latter by the absorbents. By digestion, nutritive fluid, called chyle, is extracted from the food taken into the stomach; the lacteals convey this into the blood, and partially assimilate it to that fluid; but it is not yet fit for the purposes of life. It is carried by a distinct set of vessels into the lungs, where it parts with some of the noxious principles it derived from digestion, and it also receives others from the air, which, as it were, imparts to it

vivifying properties. In this state it is returned to the heart, and this organ sends it through numberless vessels to every part, for their growth and nourishment. But the mere circulation of this fluid would not be sufficient; a portion of it must be left in each of the organs to supply the waste, and this is probably done by the minute capillary vessels of the part. Under ordinary circumstances, these vessels cannot be seen by the eye, even when aided by the microscope: they are so minute as to elude all examination in their natural state. But, small as they are, they are agents whose functions cannot be dispensed with in the animal economy. One set performs an important office in the lungs, as has been already noticed, and the other, spread throughout the system, is carrying nourishment to all the organs. The latter have received the name of the nutritive arteries. The nutritive process is a sort of secretion, by which different substances are separated from a common fluid, the blood. Thus, one set of these vessels deposits the fibrin to form the muscles, and another, the earthy and animal parts of the bone. We are wholly ignorant how this is accomplished; but of the fact there is no doubt.

'Nearly all the parts of the body are continually, during life, subjected to this process; the old particles are taken up by the absorbent vessels, and new ones are deposited in their place by the nutritive arteries. The hair, the nails, the outer covering of the teeth, the coloring matter of the skin, and perhaps the cuticle, form almost, if not the only exceptions.'

This circumstance of the continual change of the matter of our bodies, has given rise to an amusing question in regard to the evidence of personal identity. When it is announced that the materials of our bodies are incessantly changing, metaphysicians ask, in some perplexity, how know we that we are the same individuals that we were a year ago? Since within that time all the portions of matter, of which our bodies were then composed, have been exchanged for others, how are we assured that our persons have not been exchanged also,—that we really are ourselves, and not somebody else;—like the famous stocking, that had been darned until not a thread of the original article remained, and no one could ever tell whether it was the same stocking or another?

It is true, every body feels that there is no real difficulty in this case, except as a matter of theory. In reference to himself, no man needs to reason about it. He feels within himself that he is the same individual that he ever was. And

this circumstance has given rise to the theory, that it is this very consciousness which constitutes the proof of identity. A better explanation, perhaps, may be found in the manner in which the changes of substance in the animal body are effected. These changes take place only particle by particle ; and the change has respect to the individual particles, rather than to the body of which they form the several parts. Each new portion of matter, as it becomes assimilated, assumes the character of that whose place it supplies. As the sentinel who goes on duty receives the orders of his predecessor, and transmits them to his successor, so each successive particle, incorporated into the animal system, receives its impressions from those that preceded it. In this manner, not only the form and powers of the body, but the habits of the constitution, and its tendencies to disease, or its exemption from a particular disease, are transmitted through successive changes of matter, with nearly, or quite as much certainty, as if every particle of the body were perpetual and unchanging. The individual is identically the same, therefore, because the character of his physical constitution, as well as his intellectual and moral character, is the same.

Although the matter which supplies the nutrition of the body is received into the blood by the process of digestion, it is not however so immediately fitted for this its ultimate purpose. We must therefore return with our author, (for we have anticipated his course of arrangement,) and take a short notice of some of the intermediate processes. The most important of these are the Circulation of the blood, and Respiration.

There is no part of Physiology, to the improvement of which the discoveries of modern science have been so successfully applied, as to the explanation of the phenomena of Respiration. The ancients were ignorant of the true course of the circulation of the blood : and even long after that problem had been solved by the investigations of the immortal Hervey, physiologists were wholly at a loss to account for the circulation through the lungs. They saw that every portion of the whole mass of blood, as fast as it had completed its tour of duty over the general system, before it set out again to repeat the same course over the body, was sent into the lungs, and there brought under the influence of the air in Respiration. But so utterly uncertain were they of the nature of this influence,

that while some said that the purpose was to cool the blood, others thought that it was to supply heat; some, to supply, others to abstract moisture. It was reserved for the discoveries of modern Chemistry to explain the true nature of the reciprocal changes, which the blood and the air undergo in this remarkable process.

'The quantity of oxygen is diminished by respiration, and that of carbonic acid gas is increased. Expired air, instead of containing twenty-one parts of oxygen, like atmospheric air, has but eighteen parts, and contains four parts of carbonic acid gas, instead of one. Some physiologists are of opinion, that all the oxygen that has disappeared, may be accounted for by the carbonic acid gas that is formed, while others believe that a portion has united with the blood. This point may perhaps be considered as still unsettled. We shall say more of it when treating of the changes produced in the blood by respiration.

'The next point of view in which the important process of respiration is to be considered, is as to the effects which it produces on the blood that is sent to the lungs. It has been before explained, that the blood which is derived from digestion, and that which is returned by the veins from all parts of the body, is carried to the right side of the heart. It is of a dark color, and unfit for the purposes of life. It is sent by the contraction of the right ventricle to the lungs; it passes through numberless vessels of the smallest size, and is carried to the left side of the heart, of a bright scarlet color. How is this effected? We have seen above, that the quantity of carbonic acid is greater in expired, than in atmospheric air. But the oxygen, contained in the carbonic acid gas, does not account for all the oxygen that is lost. Some have supposed that a portion of it unites with hydrogen, and thus forms the watery vapor that is thrown from the lungs. This is not, however, the prevailing opinion. The fact seems to be, that in respiration, both the air and the blood part with something, and receive something from each other. The air loses a portion of its oxygen, part of which goes to the formation of the carbonic acid, and the remainder unites with the blood; the blood also parts with some of its carbon, which unites with the oxygen taken into the lungs, and is then thrown out in the form of carbonic acid; and another part of the oxygen is absorbed by the blood. Thus it appears that the blood parts with a portion of its carbon, and at the same time gains some oxygen.

'This change in the blood in respiration has been called the oxygenation of the blood, by those who explained it on the supposition, that oxygen united with the blood in its passage through

the lungs. It has also been called the decarbonization of the blood, by those physiologists who believe that the change is produced by the discharge of carbon. The truth seems to be, that the blood is both oxygenated and decarbonized by respiration ; that is, that a portion of the oxygen taken into the lungs unites with it, and at the same time the blood throws off carbon in a volatile state, which unites with another portion of oxygen, while the air, at the same time, loses some oxygen and receives some carbon, and thus forms carbonic acid gas.'

' To whatever circumstance this change may be owing, it is certain, that it is one essential to life. If it were completely suspended, even for a moment, death would follow. The black blood, or the blood of the veins, or venous blood, as it is called, cannot support the animal functions ; they require the stimulus of the red arterial blood.

' If respiration be suspended, the heart will for a time continue to throw the blood to the lungs ; but when all the air is exhausted in these organs, so that they return purple blood to the left side of the heart, death immediately follows. This is owing, in great measure, to the circumstance that black blood is now of course thrown into the coronary arteries, the nourishing arteries of the heart ; and this organ ceases to act, when not excited by arterial blood. The action of the brain, too, cannot be continued for an instant, without the stimulus of oxygenated blood, and all the organs of the body are dependent on the brain and nervous system for their power of action.'

It should not be inferred, as it sometimes has been, from the statement of these facts, that the presence of carbon in the blood is necessarily poisonous, under all circumstances ; or that all the oxygen is withdrawn from venous blood. Both these substances exist in large quantities both in arterial and venous blood, and in every other animal product. It is a difference of proportions merely, in the two kinds of blood ; and this difference is so small as scarcely, if at all, to be detected by direct analysis. Our knowledge of it is derived more from the effects on the air respired, than from experiments, made on the blood itself. It may seem strange, that a change of proportions so slight as to be appreciable only by inference, should be so important in its effects. But here is our limit between observation and conjecture. The fact is well established, not only that respiration is essential to life, which every body has always known, but also that the chemical changes produced in respiration are equally indispensable. It is worthy of remark, too, that these changes

are essentially the same, in all living bodies, and are equally indispensable to all, from the highest animal, to the lowest vegetable.

Connected with Respiration, are the remarkable phenomena of animal heat. . . The human body is capable of preserving a uniform temperature, for an indefinite length of time, through all the changes of a climate, whose extremes are more than a hundred degrees asunder ; and for a limited period the power is much greater. It is manifest that to keep up such an equilibrium, especially in a medium, as in our climate, many degrees colder than the body, must demand a great power of producing heat. It might have been supposed that such a manufactory might easily be discovered, yet physiologists have not been able to point out satisfactorily its true sources. When it came to be known, that the changes which the air undergoes in respiration are entirely similar to the effects produced upon the same fluid by combustion, it was but natural to infer that heat is in like manner derived from the process. Consequently, physiologists have been constantly looking to this process for an explanation of the production of animal heat, ever since the true composition of the atmosphere was made known. It was objected, that the lungs are no hotter than other parts of the body, as it might be expected they would be, if they manufacture the heat for all the other parts. But

' Dr. Crawford brought forward an explanation of the manner in which animal heat is generated, that was for a time adopted by most physiologists. He agreed in opinion with Dr. Black, that heat was generated in respiration, as in combustion, by the conversion of oxygen and carbon into carbonic acid gas ; and the reason, which he assigns for the fact that the lungs have not a much greater degree of heat than the other parts of the body, is, that the arterial blood has a greater capacity for caloric than the venous blood, and that a part of the heat formed in the lungs is absorbed by the arterial blood, and remains in it in that state which is known by the name of latent heat. When the blood is conveyed to the various parts of the body, the heat is given out whenever the arterial blood is converted into venous, as it is in the various processes of nutrition.'

This is so simple and beautiful a theory, that it is a pity it is not true. But the animal system never works so entirely by physical laws. Dr. Crawford indeed details a long course of

experiments, to establish the truth of his opinion. He calculated very carefully the capacity for heat, not only of the inspired and expired air, and the arterial and venous blood, but also that of the various articles of food, and found every thing favorable to this theory. The result to which he came was, that the change of capacity for heat in the blood during respiration is sufficient to produce a demand for 207 degrees of heat, to remain latent in the arterial blood, so as to cause no actual change of temperature. The corresponding change in the air he found sufficient to set free 4,650 degrees of heat. It only remained to bring these two results together, to form a perfect test of their correctness. But this he omitted to do.

It is obvious that the increase of temperature, caused by a given quantity of heat, other things being equal, is inversely as the quantity of matter. A pint of hot water, added to a hundred pints a hundred degrees colder, will raise the temperature of the hundred just one degree. Now if Dr. Crawford's positions are true, the quantity of matter, in that portion of air which is changed in respiration, must correspond exactly with the quantity of matter in the portion of blood which it supplies with latent heat. These quantities cannot indeed be ascertained with entire exactness; but something is known in regard to them. Taking the highest estimate that has ever been made of the quantity of oxygen consumed in each respiration, its actual weight does not amount to one grain; while at least seven ounces, or 3,360 grains of blood, are presented to the action of the air in each respiration. One grain, heated 4,650 degrees, would raise 3,360 grains a little more than one degree; whereas Dr. Crawford's positions require 207 degrees, besides the quantity of heat lost in raising the temperature of the remaining portion of respired air, and in various other ways.

This difficulty, however, in regard to animal heat, is scarcely greater, than that of explaining the production of heat in ordinary combustion, from which the analogy is drawn. The ordinary explanation of the process of combustion, with which most chemists appear to be satisfied, attributes the production of heat, in the same manner to a change of capacity for heat, effected during the process. Upon this hypothesis, according to all the known laws of heat, the burning of gunpowder should be a most freezing operation; for all the ingredients, even the oxygen, are in a state of comparatively small capacity, and

by the combination in burning they pass into states requiring immense proportions of latent heat. The truth is, many of the laws of heat are too imperfectly known to render it safe to found any confident opinions upon them, even in regard to physical science ; still less in their application to the operations of organized, living beings.

After all, it is not easy to escape altogether the impression, that animal heat is in some way dependent upon or connected with respiration. Direct experiments on animals, designed to ascertain this point, have repeatedly been tried ; but their results are contradictory. Mr. Brodie inferred from his experiments, that no heat is produced by respiration, while Dr. Wilson Philip, M. Legallois, and others, have come to a different conclusion. The truth probably is, that artificial respiration in animals keeps up the animal heat, just in proportion to the extent to which it preserves the other vital actions. All the functions of life are not destroyed at the same moment ; and in some modes of death, certain of these functions are retained in action much longer than when death takes place in other ways. Animal heat is one of these functions ; and it is preserved to a certain extent by artificial respiration, whenever that respiration is so managed as to prolong the powers of life. The same result may be produced without artificial respiration. If two animals of the same character and size are killed, in different ways, so as in one to destroy suddenly *all* the functions, while in the other the *entire* death of all the parts follows more slowly, although both animals are, in the ordinary sense of the term, equally dead from the same moment, the first will cool much more rapidly than the last. It is not impossible, although we see little evidence of it, that the chemical effects of respiration have something to do with the production of heat ; and it is no proof against this hypothesis, that we are not able to explain the manner in which the development of heat may arise ; since, as we have just observed, we are equally ignorant in regard to the origin of the heat produced in combustion.

' These, and other experiments of a similar character, (the experiments of Dr. Philip and M. Legallois,) have induced most physiologists of the present day to adopt what is usually called the chemical theory of the generation of animal heat. It must be confessed, however, that it is not without its difficulties,

but at the same time it cannot but be acknowledged, that it is embarrassed with fewer than any other that has ever been proposed. Though it is called a chemical theory, it is so only in a limited sense, the laws of chemistry being, as in all the other operations, that go on in the living body, modified and controlled by the laws of vitality. The brain and nervous system no doubt perform an important part, if not in the generation, at least in the evolution of animal heat.

'There is one fact worthy of notice, as it seems to show that there must be an intimate connexion between respiration and animal heat; and that is, that in those animals whose respiratory apparatus is the most extended, the temperature is uniformly highest. Birds, whose organs of breathing extend over a large part of the body, and who consequently require a great quantity of air, have a higher degree of temperature than other animals: it is twelve degrees above that of man; while in cold-blooded animals, as fishes, whose temperature is not much greater than that of the medium in which they live, but a very small quantity of blood at any one time is subjected to the effects of respiration.'

We have not room to prolong our remarks, and notice the other subjects of interest discussed in this little volume. Nor is it necessary. Enough we trust has been said, to exhibit something of the character of the work, and of the able and faithful manner in which the author has executed his purpose.

We would hope that the publisher will put a portion at least of future editions into the dress of a parlor book. There is something in the air of a school-book, which does not always carry pleasant associations with it into the parlor. However useful this book may be for the higher classes in schools (and highly useful to them, we are persuaded it will be,) we believe it will be even more valuable to those whose school days have gone by. Those who have before studied Physiology as a science, will find in it a convenient and agreeable summary of the best modern opinions on the different subjects. Those to whom the whole subject is new, will find it filled with important instruction, conveyed in an intelligible and pleasant manner.